AASHTO T 99 AND T 180
MOISTURE-DENSITY RELATIONS OF SOILS

Conduct this procedure according to AASHTO T 99 or AASHTO T 180.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

The NDDOT modifies this standard to only allow Method A.

SCOPE:

The moisture-density relationship test is also called the Proctor test. This test method determines the relationship between the moisture content and the density of soils compacted in a mold. Two different standards of moisture-density relationships are presently in use by the NDDOT. They vary mainly in the compaction energy applied to the soil in the mold. The two standards and their features are summarized below.

FEATURE	AASHTO T 99	AASHTO T 180
Weight of Compaction Rammer	5.5 lbs	10 lbs
Distance of Drop	12"	18"
Number of Soil Layers	3	5
Diameter of Mold	4"	4"
Soil Passing Sieve Size	No. 4	No. 4
Rammer, blows per layer	25	25

REFERENCED DOCUMENTS

AASHTO T 217, Determination of Moisture in Soil by Means of Calcium Carbide Gas Pressure Moisture Tester (Speedy)
AASHTO T 265, Laboratory Determination of Moisture Content of Soils
ASTM D 2167, Density and Unit Weight of Soil In Place by the Rubber-Balloon Method
ASTM D 4643, Microwave Method of Drying Soils

APPARATUS

Compaction equipment including density mold, base and collar, compacting rammer and guide
Balance, readable to 0.01 lbs (5 g)
Oven
No. 4 (4.75 mm) sieve
Mixing tools
Moisture sample cans with lids
Straightedge, 10” long
Knife

SAMPLE SIZE

A representative soil sample of approximately 35 lbs (15.9 kg) is required for the multi-point moisture density relationship test. Approximately 7 lbs (3.2 kg) is required for the one-point moisture density relationship test.

MULTI-POINT MOISTURE DENSITY RELATIONSHIP-MECHANICAL & MANUAL PROCEDURE

Record information on SFN 10063. Calculate and record to the accuracy indicated.

If the soil is damp when received, dry the soil until it is easily crumbled under a trowel. The soil can be air dried or oven dried at a temperature up to 140°F (60°C). Break up the soil chunks so that the entire sample passes through the No. 4 sieve. Avoid reducing the natural size of the particles. Discard any individual particles of material retained on the No. 4 sieve or organic material. Divide the sample into five representative samples of 7 lbs each.

Thoroughly mix the first test sample with water to dampen it approximately four percentage points below optimum moisture. A good indication of a soil being moist enough for the first point is if the soil barely forms a “cast” when squeezed together. The specimen shall be placed in moisture-proof container and covered to prevent moisture loss. Mix the remaining specimens in the same manner as test sample one, increasing the water content by approximately one or two percentage points (not exceeding 2.5%) over each preceding specimen. This can be accomplished by adding approximately 60 mL of water. Allow soil samples to cure in moisture-proof containers for a minimum of 12 hours.

Weigh the empty mold without the base plate or collar and record to the nearest 0.01 lb (5 g).

Add sufficient material from test sample one to the mold to produce a compacted layer of approximately 1-3/4” for T 99, or 1" for T 180. Gently level the soil surface in the mold. *Using a manual compaction rammer or a similar device with a 2" face (50 mm), lightly tamp the soil until it is no longer loose or fluffy. Compact the soil with 25 evenly distributed blows of the compaction rammer. After each layer, trim any soil along the mold walls that has not been compacted with a knife and distribute on top of the layer.

> *When completing this process using a mechanical compactor, it is recommended to use a spare or extra replacement rammer.

When using a manual compactor, remember to hold the rammer perpendicular to the base of the mold and lift the rammer to its maximum upward position.

Repeat this procedure adding more soil from the same sample each time so that at the end of the last cycle, the top surface of the compacted soil is above the top rim of the mold when the collar is removed.

Remove the collar and trim off the extruding soil level with the top of the mold. In removing the collar, rotate it to break the bond between it and the soil before lifting it off the mold. This prevents dislodging chunks of compacted soil when lifting the collar off. The trimming consists of many small scraping motions with a knife or straightedge.

After trimming the soil level with the top of the mold, clean all loose material from the outside of the mold. Weigh the soil and mold to the nearest 0.01 lb (5 g) and record.

WET DENSITY CALCULATION

Calculate and record the wet density to the nearest 0.1 lbs/cu.ft. (pcf).

Wet weight of soil = (Weight of mold + Soil) - Weight of mold

Wet density, lbs/cu.ft. (pcf) = Wet weight of soil/Volume of mold

Remove the soil from the mold and slice through the center vertically. Obtain a representative sample of approximately 100 g from one of the cut faces. Take the sample from the full length of the inside of the soil cylinder. Place the moist sample in a container, cover and weigh. Record the weight of the wet soil. Record this and all moisture weights to the nearest 0.1 g.

Oven dry the sample according to T 265 at a temperature of 230 ± 9°F (110 ± 5°C).

MOISTURE CALCULATION

Calculate and record percent moisture to the nearest 0.1%.

$$A = [(B-C)/C] \times 100$$

A = Percent moisture
B = Mass of original sample
C = Mass of dry sample

DRY DENSITY CALCULATION

Calculate and record dry density to the nearest 0.1 lbs/cu.ft. (pcf)

Dry density, lbs/cu.ft. (pcf) = (Wet density x 100)/(100 + Percent moisture)

Using specimen number two, repeat the compaction procedure previously described. Continue this process with the remaining samples until there is a decrease in the wet density per cubic foot.

GRAPH

The objective of this procedure is to determine the maximum dry density and optimum moisture content for this particular soil. Based on the results obtained from conducting consecutive Proctors with changes in moisture, plot each test result on the cross-ruled area on the form with the moisture content plotted on the abscissa (x) and the density on the ordinate (y). Graphs T 99 and T 180 are found at the end of this procedure.

After all the results are plotted, draw a smooth flowing curve through or close to the plotted points. From the peak of the curve, determine the maximum dry density and optimum moisture.

REPORT

Report maximum dry density to the nearest 1 lb/cu.ft. (pcf) and optimum moisture to the nearest 0.1%.

NOTES

During compaction the mold shall rest firmly on a dense, uniform, rigid and stable foundation or base. This base shall remain stationary during compaction process. Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: a block of concrete with a mass not less then 200 lb (90 kg) supported by a relatively stable foundation; a sound concrete floor; and for field application such surfaces as are found in concrete box culverts, bridges, and pavements.

The moisture-density test is used to establish a value of density on which construction requirements can be based. It is a test conducted on a single identifiable soil and results may vary considerably between different soils.

Make every effort to space the moisture content no further apart than 2.5% in order to accurately determine the maximum dry density and optimum moisture content.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

ONE-POINT MOISTURE DENSITY RELATIONSHIP WITH TYPICAL MOISTURE-DENSITY CURVE METHOD:

After analyzing a large number of both T 99 and T 180 moisture-density curves that generally represent statewide soil types, it was found the curves follow the trends shown on the graphs on the following pages. The graphs with the following procedure may be used in place of performing the entire moisture-density relationship test. It is recommended that the multi-point moisture density relationship be used whenever possible.

PROCEDURE

The procedure that follows is written for a test using one sample of approximately 7 lbs (3.2 kg) of material. Thoroughly mix the soil sample with water and dampen it approximately to, but not over optimum moisture. Conduct a proctor test as previously described in the multi-point moisture density relationship.

GRAPH

Use the following graph, whichever is appropriate, either T 99 or T 180, to locate the point defined by the two values obtained from the one-point moisture density test.

If the point lies directly on a curve, follow this curve to its peak and determine the maximum dry density and optimum moisture content. If the point lays in-between two curves, follow the two curves to their peaks and interpolate the maximum dry density and optimum moisture content.

REPORT

Report the maximum dry density to the nearest 1 lb/cu.ft. (pcf) and optimum moisture to the nearest 0.1%.

NOTES

When D 2167, the rubber balloon method, is used for the density test, use the same material from the hole for the one-point determination. To get sufficient material, enlarge the hole after the rubber balloon test is complete and use the additional material collected.

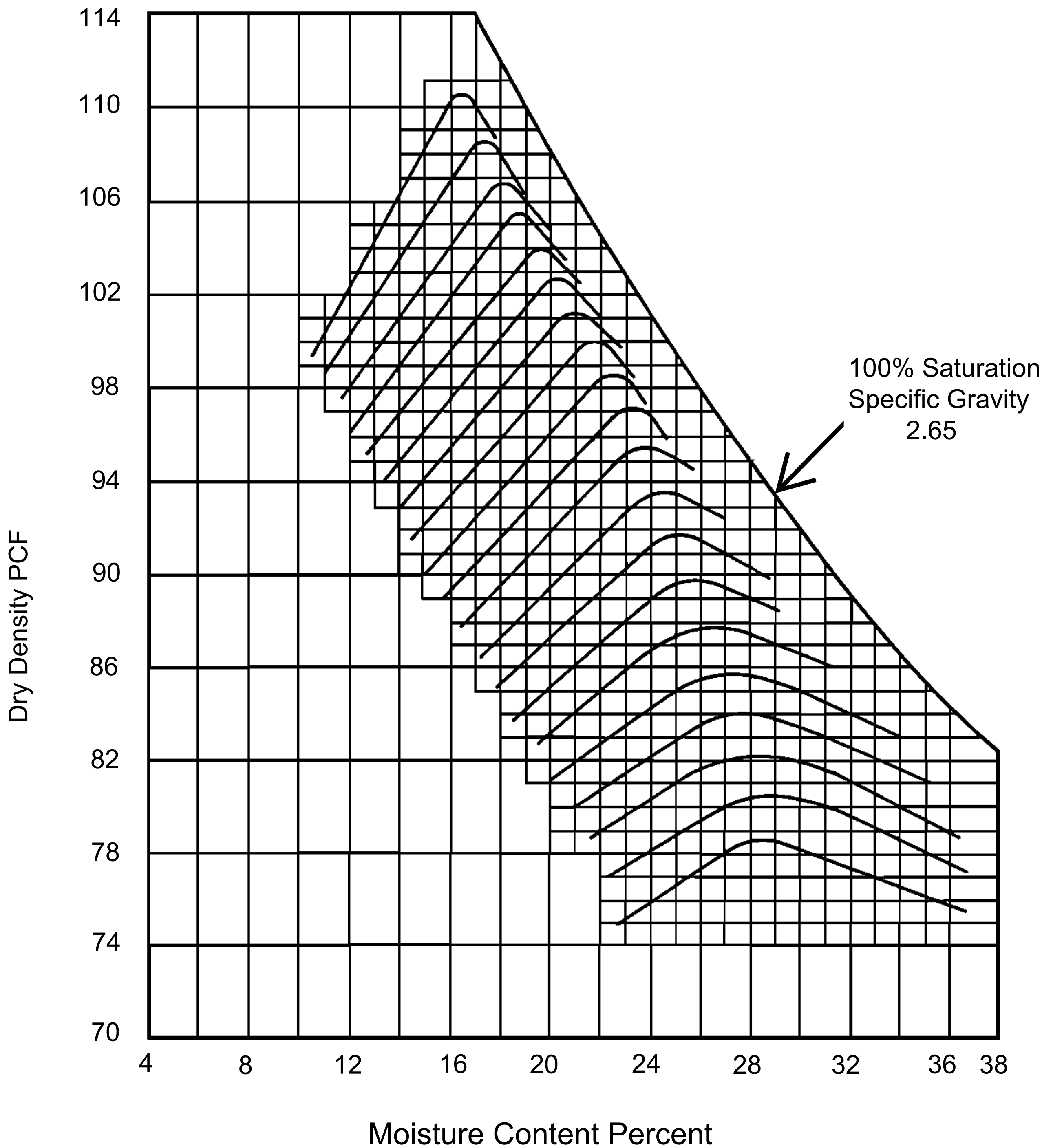
In order to perform the test in conjunction with and at the same location as the in-place density test, use the steel-capped, wooden pedestals supplied with the molds to support the mold base plate. During compaction, place the mold and pedestal on firm level ground.

Determine moisture content according to T 217, D 4643, or T 265.

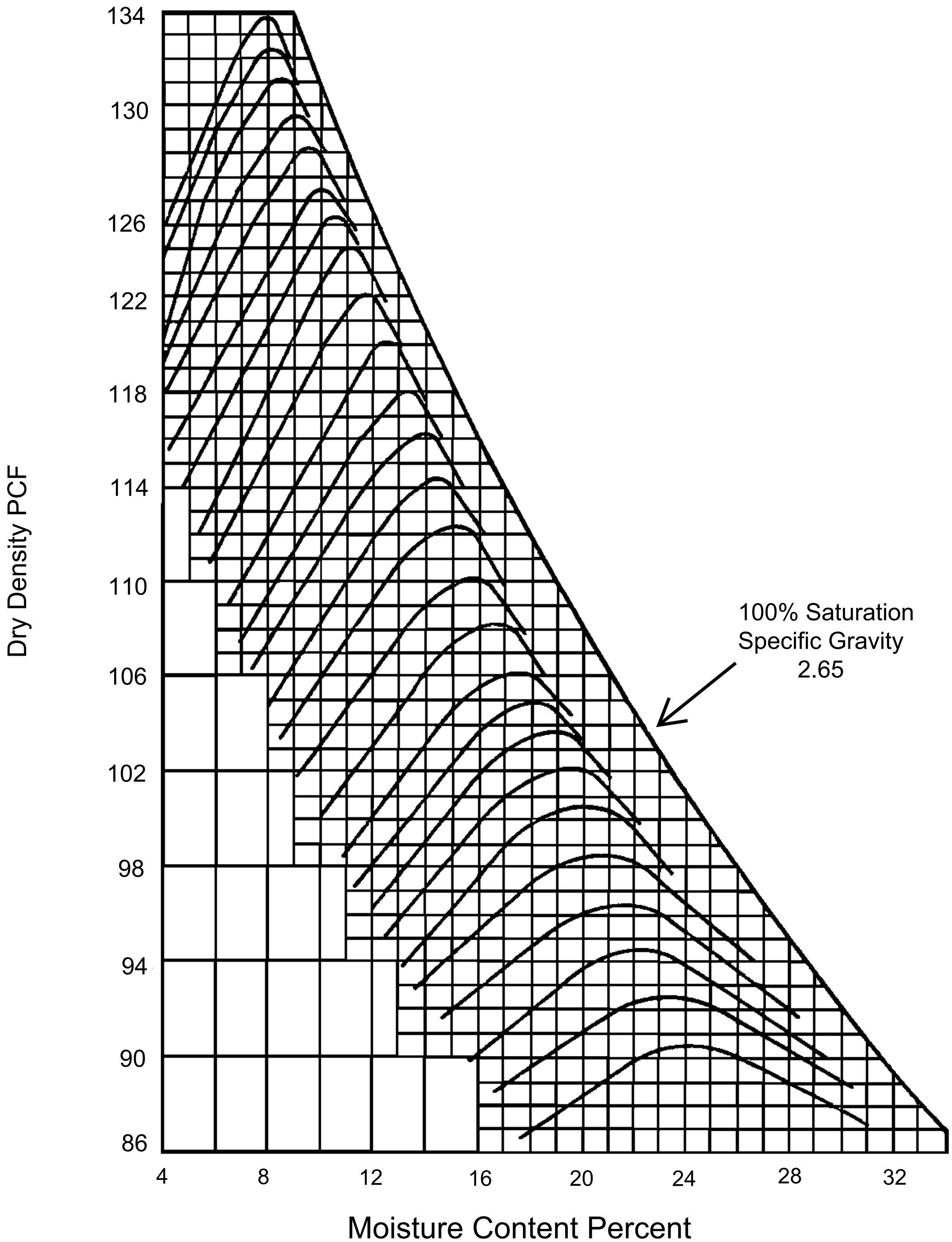
When using the graphs, a soil on the wet side of optimum could result in a substantial error when selecting the maximum dry density. Most specifications require the moisture content to be at or above optimum. It can be assumed that this is the condition that most samples are in. If the sample is judged to be slightly wetter than optimum, dry it to a condition slightly drier than optimum before compacting.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.



Typical Moisture-Density Relationship Curves for T-99 Compaction



Typical Moisture-Density Relationship Curves for T-180 Compaction